

Usefulness of ensemble forecasts from NCEP Climate Forecast System in sub-seasonal to intra-annual forecasting

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Bias Correction in Subseasonal to Interannual Predications
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Acknowledgement

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- National Center for Atmospheric Research (NCAR), Boulder CO
- Reference

Kumar, S., P. A. Dirmeyer, and J. L. Kinter III (2014), Usefulness of ensemble fore- casts from NCEP Climate Forecast System in sub-seasonal to intra-annual forecasting, *Geophys. Res. Lett.*, 41, 3586–3593, doi: 10.1002/2014GL059586.



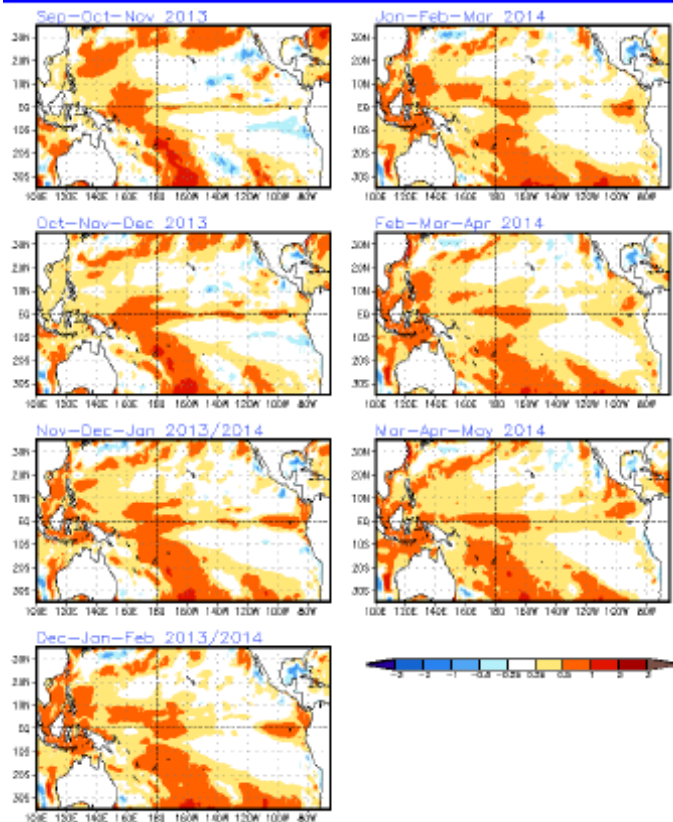
Overview

- ☐ **Motivation and Objective**
- ☐ **Anomaly Calculation/Bias Correction**
- ☐ **Hypothesis Testing**
- ☐ **Results**
- ☐ **Conclusions**
- ☐ **Interpretation for the operational forecast**

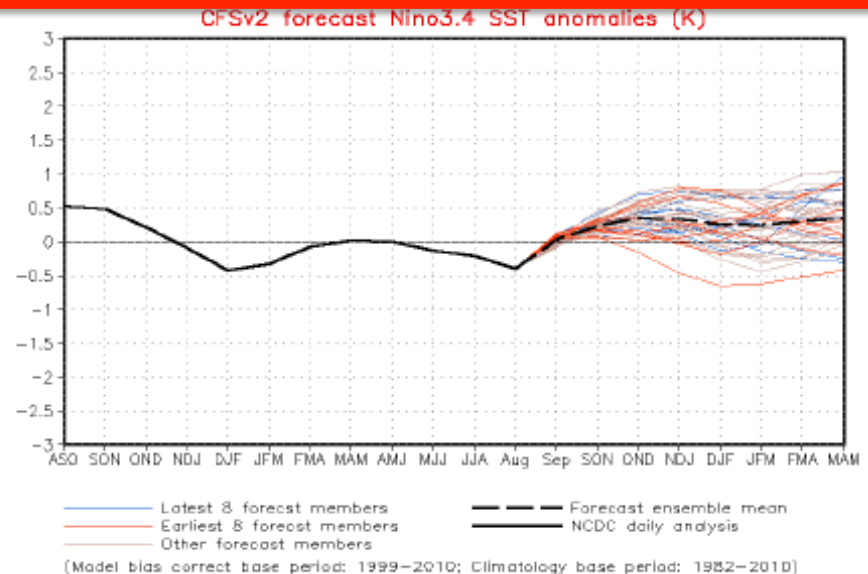
Motivation: 2014 ENSO Forecast



SST Outlook: NCEP CFS.v2 Forecast Issued 8 September 2013

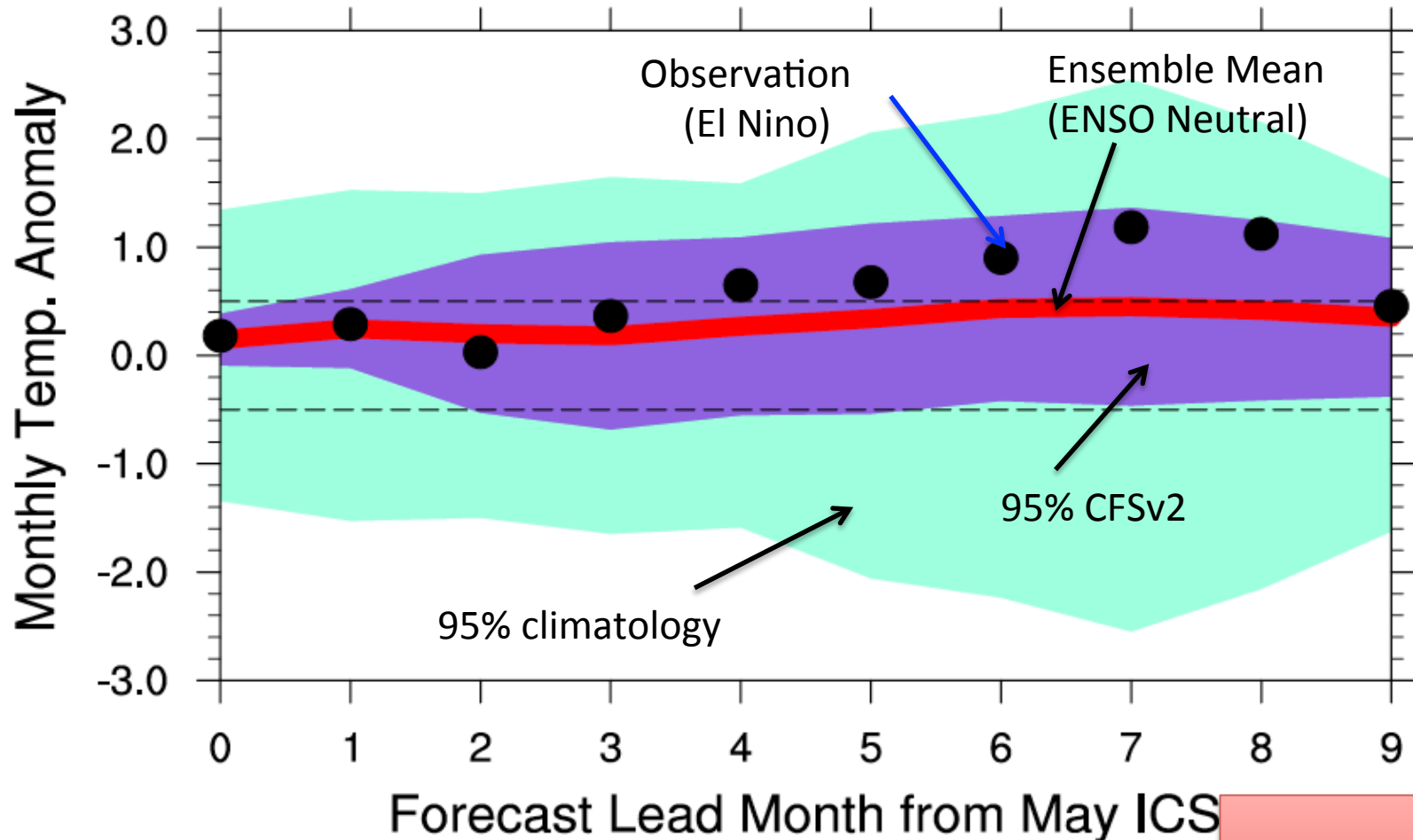


The CFS.v2 ensemble mean (black dashed line) predicts ENSO-neutral conditions into early 2014.



Motivation

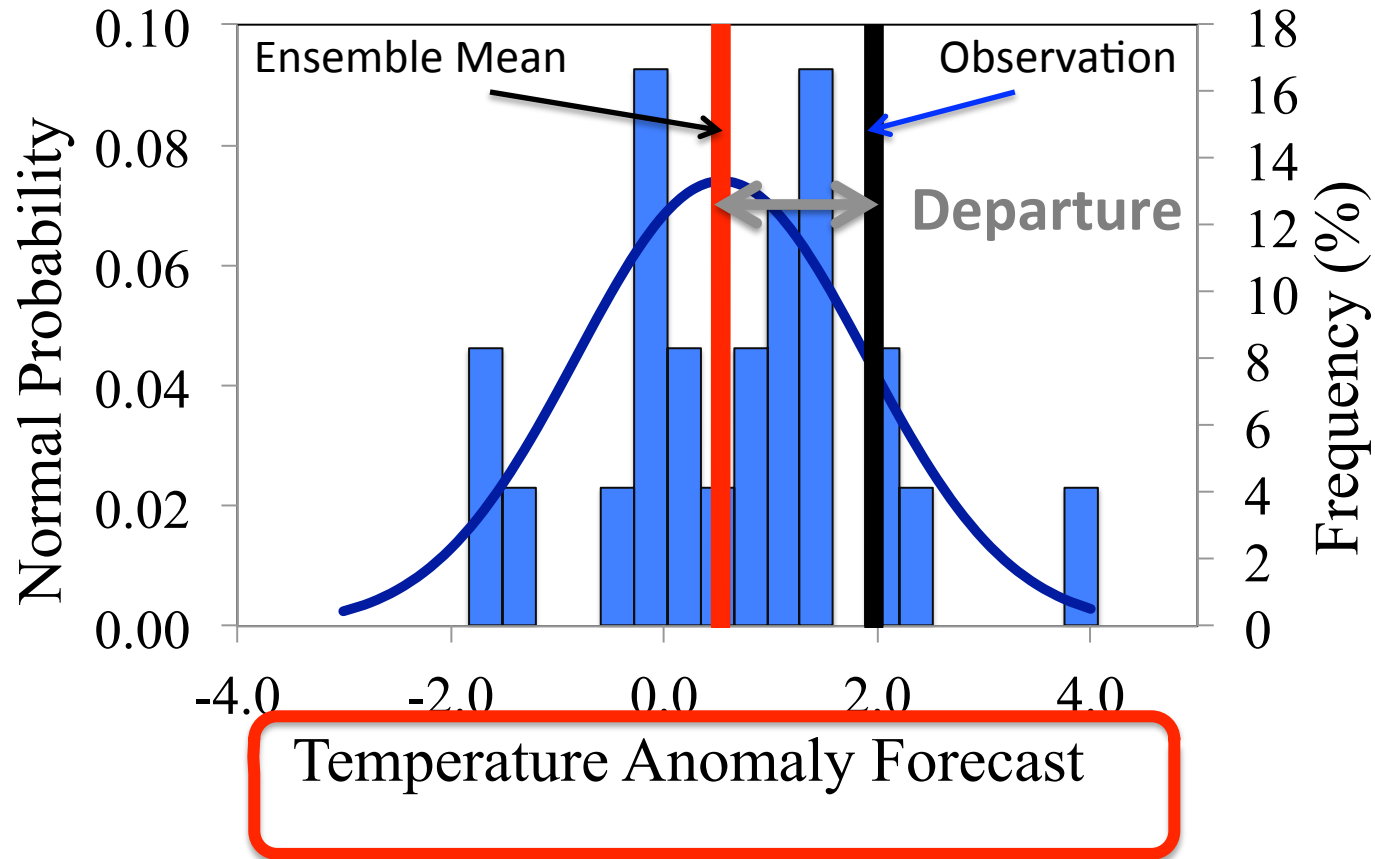
2006 ENSO Forecast



Forecasts are referred by their month of initialization

24-member SST anomaly forecast in Nino3.4 region using **May initial conditions** in 2006

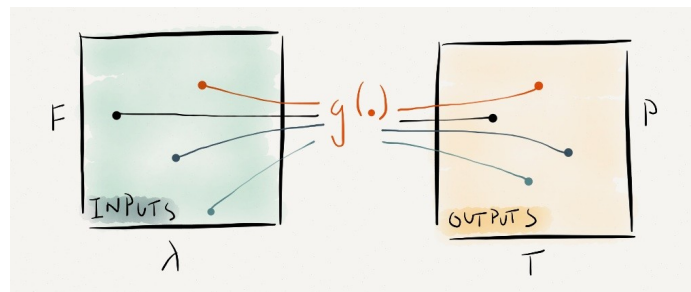
Objective 1: Quantify departure of ensemble mean from observation



Two Month Lead (July, 2006) Temperature Forecast in the Midwestern United States using May 2006 initial condition

Perfect Model Framework

- Observations => CFSv2 Reanalysis data
- Issues of observational uncertainties and deficiency in model parameterization are mitigated to some extent
- Likely to provide an upper bound of predictability in the climate system



Anomaly Calculation/Bias Correction

1. Absolute Anomaly Departure (AAD)

$$AAD_{m,l,y} = \frac{abs \left[\left(\frac{1}{n} \sum_{i=1}^n fA_{i,m,l,y} \right) - OA_{m,l,y} \right]}{s_{m,l,y}}$$

$$fA_{i,m,l,y} = f_{i,m,l,y} - \frac{1}{p} \sum_{y=1}^p \left(\frac{1}{n} \sum_{i=1}^n f_{i,m,l,y} \right) \quad OA_{m,l,y} = O_{m,l,y} - \frac{1}{p} \sum_{y=1}^p (O_{m,l,y})$$

Forecast anomaly relative to forecast climatology from the corresponding month initialization month (m) and lead time (l)

Observation anomaly relative to observation climatology

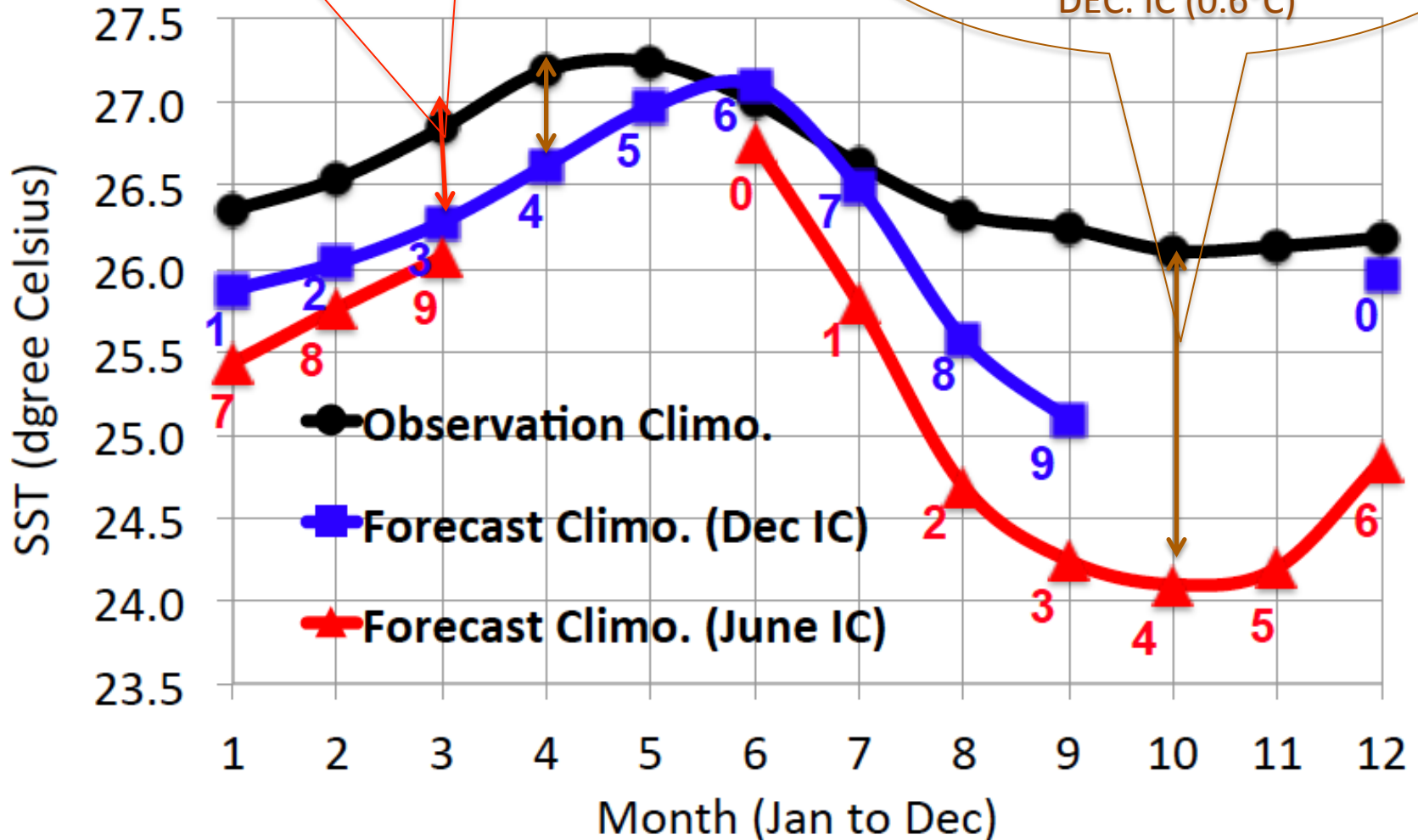
Two different climatology were used for anomaly calculations one for forecast anomaly and another for observation anomaly

$s_{m,l,y}$ is the standard deviation calculated across 24-member ensemble reforecasts

Why?

2. FORECAST BIASES DO NOT NECESSARILY GROW WITH LEAD TIME (e.g. 2°C at 4 month lead, and 0.8°C at 9 month lead [EFFECT OF SEASONALITY])

1. AT A GIVEN LEAD FORECAST BIASES ARE TIED TO THEIR INITIALIZATION MONTH e.g. JUNE IC (2°C) or DEC. IC (0.6°C)



SST Climatology in NINO3.4 region

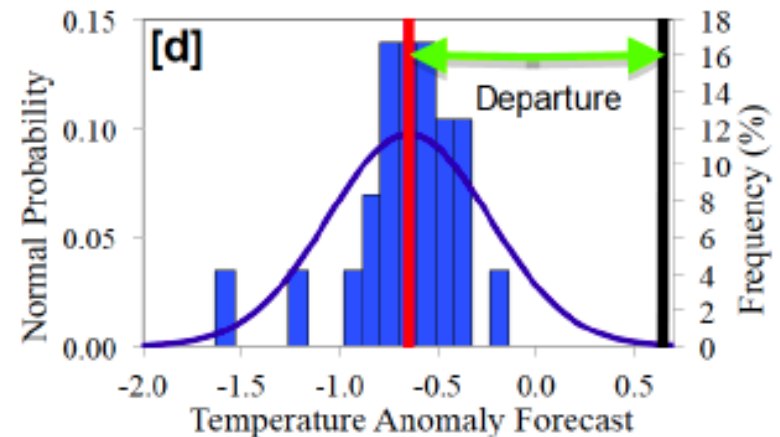
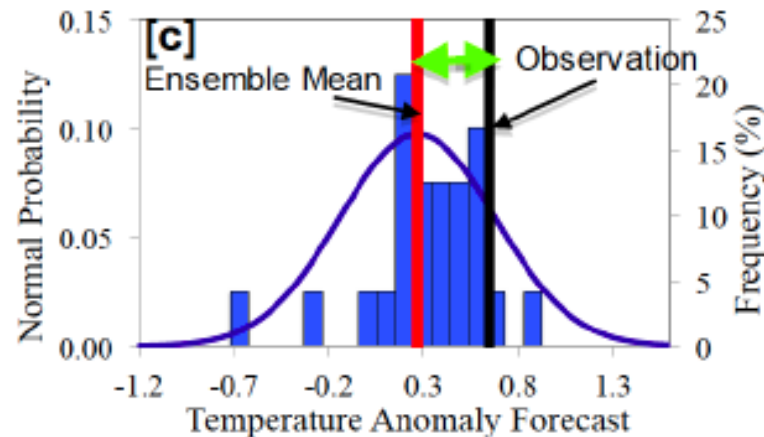
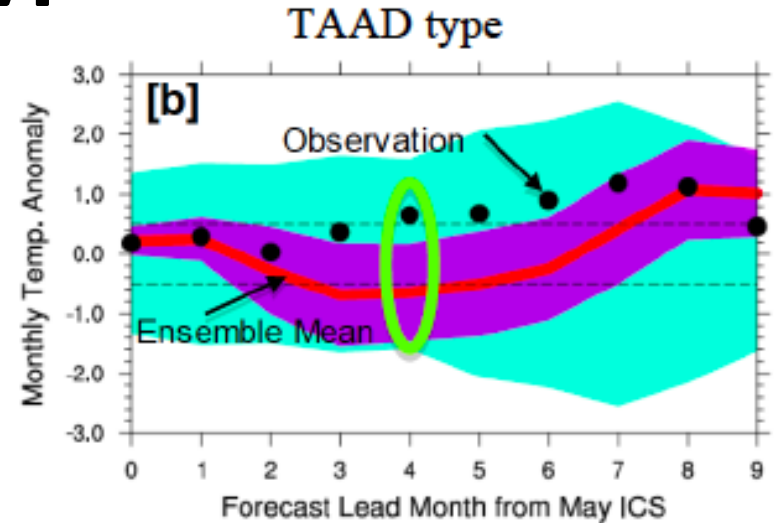
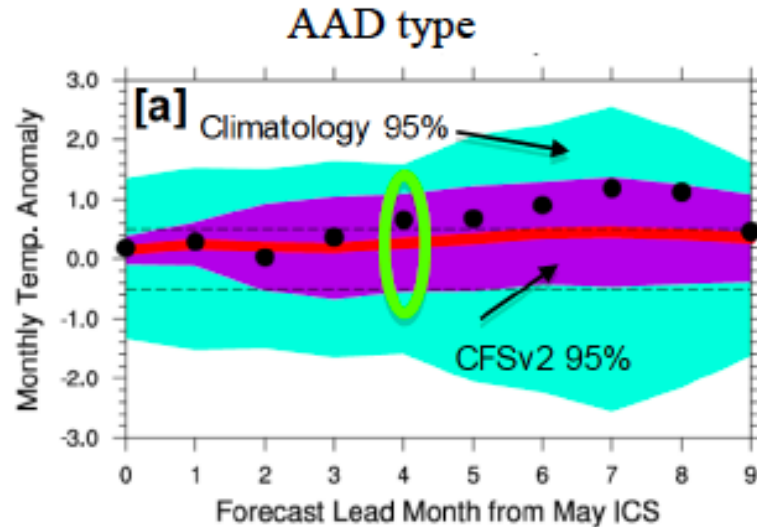
2. Traditional Absolute Anomaly Departure (TAAD)

$$TAAD_{m,l,y} = \frac{abs \left[\left\{ \left(\frac{1}{n} \sum_{i=1}^n f_{i,m,l,y} \right) - \left(\frac{1}{p} \sum_{y=1}^p o_{m,l,y} \right) \right\} - OA_{m,l,y} \right]}{S_{m,l,y}}$$

Observation climatology is used to calculate forecast anomaly as well as the observation anomaly

Two types of anomaly calculation /bias correction methodologies (AAD and TAAD) are compared to their forecast skills.

AAD versus TAAD type ENSO Forecast



24-member SST anomaly forecast in Nino3.4 region using
May (m) initial conditions in 2006 (y)

Hypothesis Testing

Null Hypothesis (H0): Observations (anomaly) are randomly distributed about the ensemble mean forecasts (anomaly forecasts)

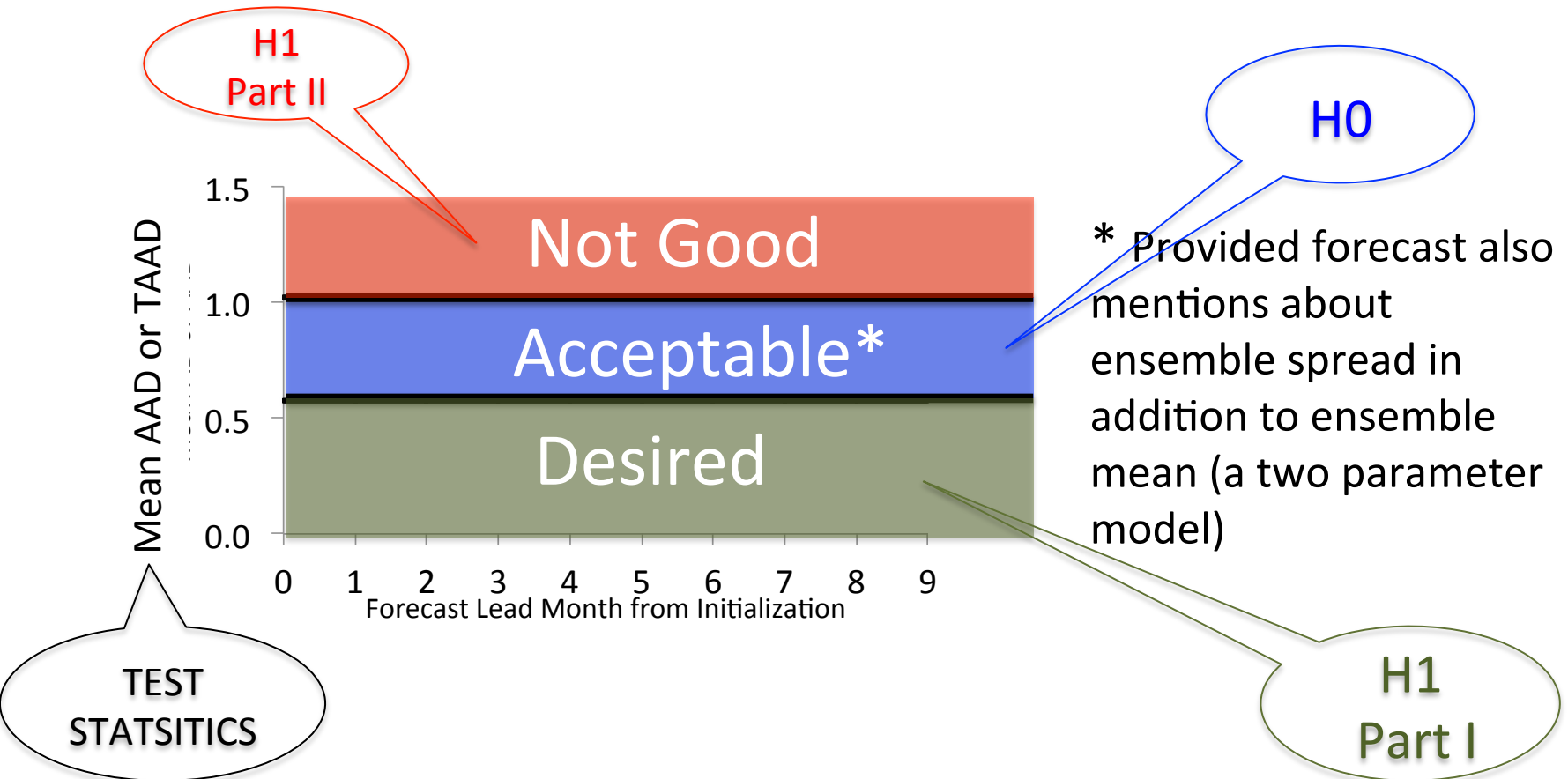
- White noise hypothesis
- Mean = 0, Standard deviation = ensemble forecast (anomaly) standard deviation

Alternative Hypothesis (H1): Part I - Observations (anomaly) and ensemble mean forecasts (anomaly forecasts) are statistically indistinguishable i.e. absolute departure ~ 0 . **Part II** - the ensemble mean forecast is too far away from the observation that may fall outside the forecast ensemble 95% range

- ☐ The hypothesis testing was designed using the property of half normal distribution
- ☐ If x has a white noise Gaussian distribution (mean = 0, and standard deviation = 1) and $u = \text{abs}(x)$, then u has a half-normal distribution
- ☐ See Kumar et al. (2014) for details

Hypothesis Testing

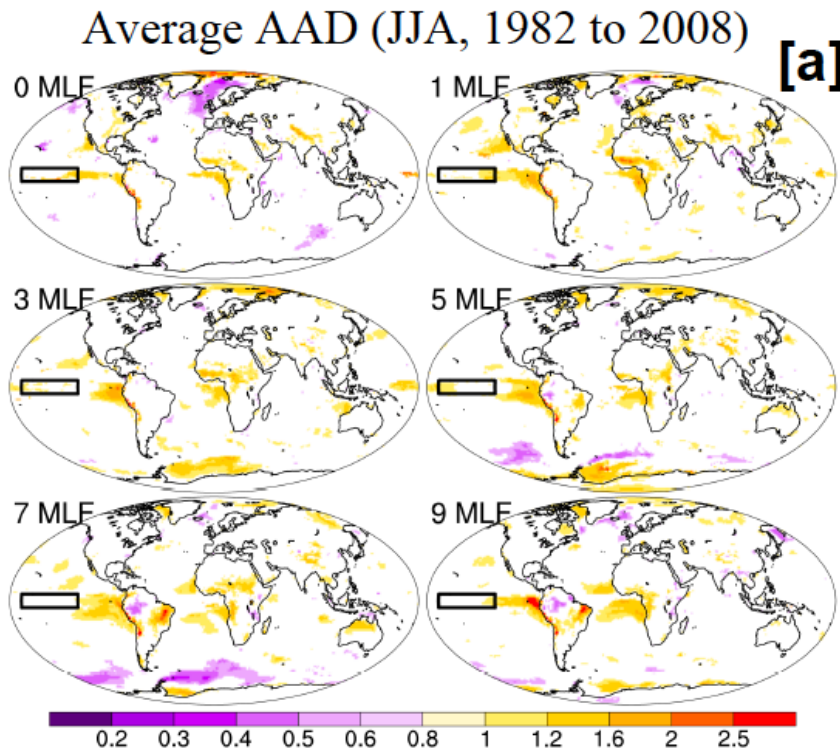
A pictures view



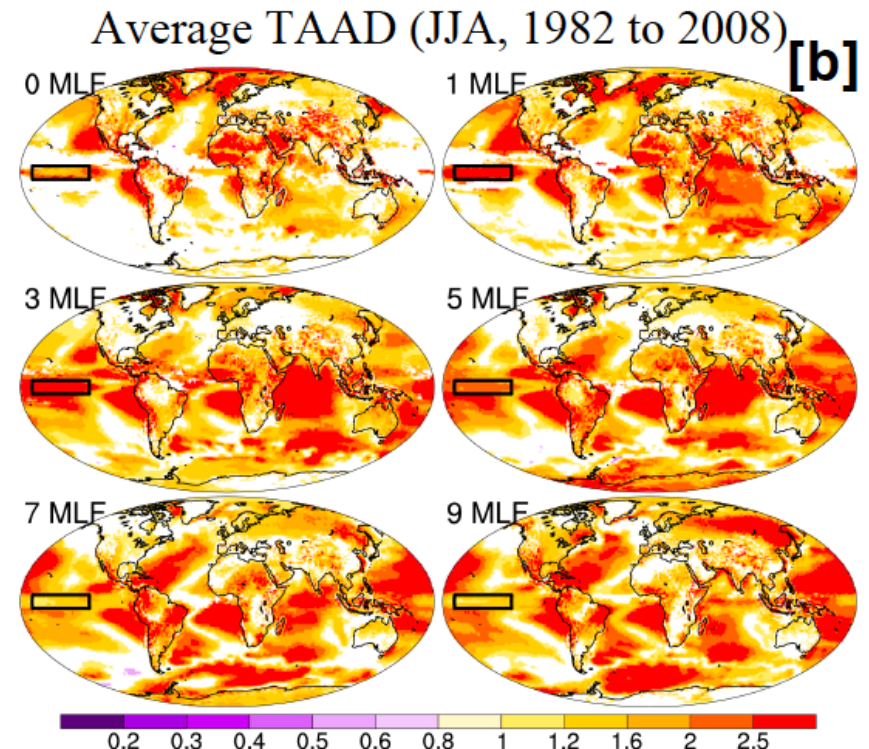
- For a large sample size (~ 30)
- Using re-forecast data from 1982 to 2008

Result of Hypothesis Testing

- Test statistics (mean AAD or mean TAAD) are calculated for each month initialized forecast and at each lead time (0 to 9 month lead forecasts [MLF])
- Average values for the forecasts initialized in JJA is shown here



AAD Type



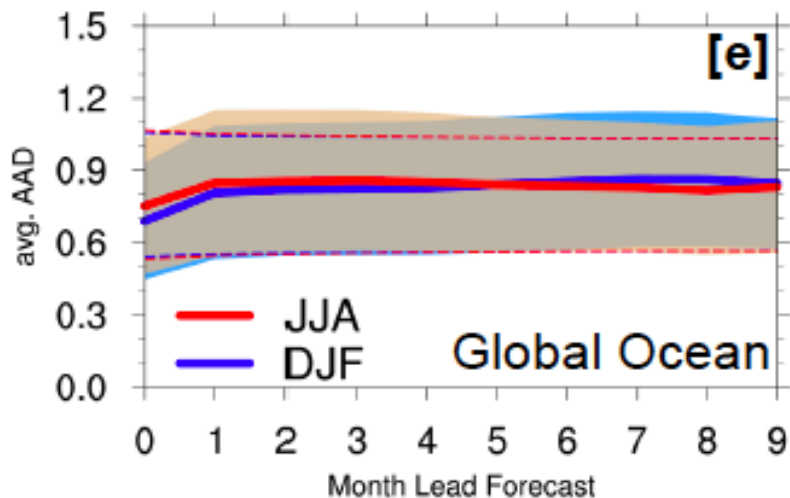
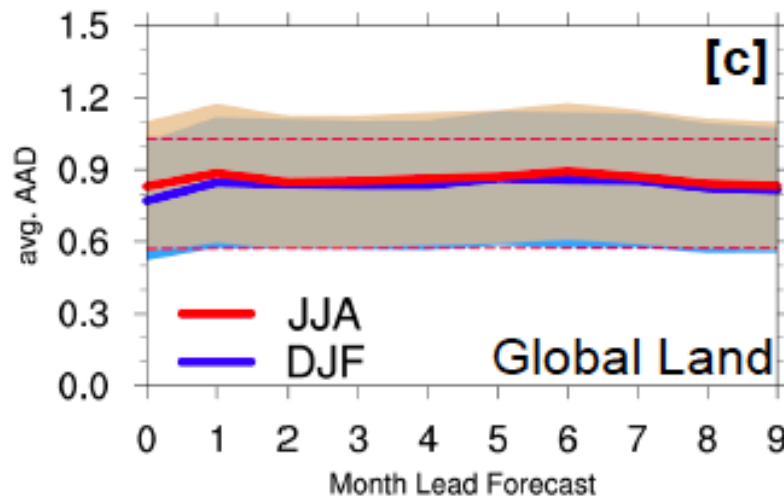
TAAD Type

Color shading are shown only when ***H0 is rejected***

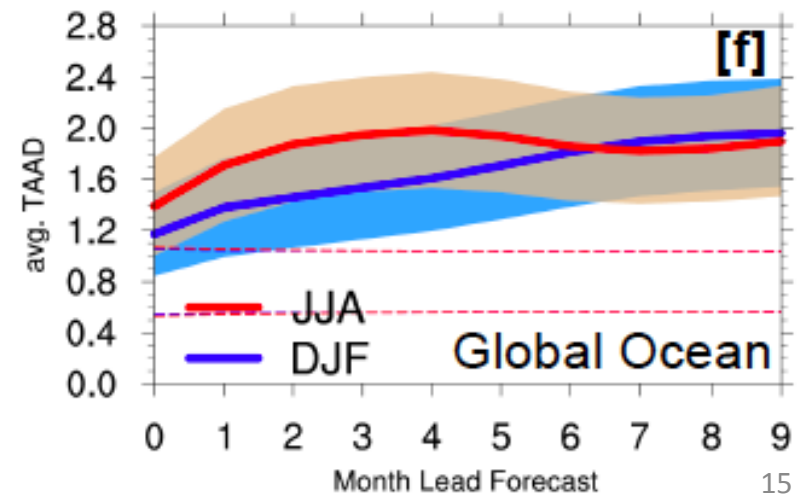
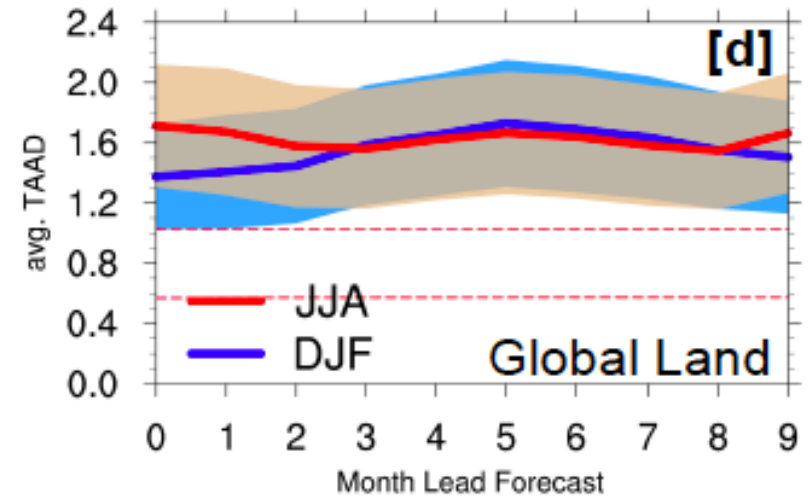
Blue color – H1 Part I; Red color – H1 Part II

Similar results for JJA and DJF Initialized Forecasts

AAD Type (H0 not rejected)



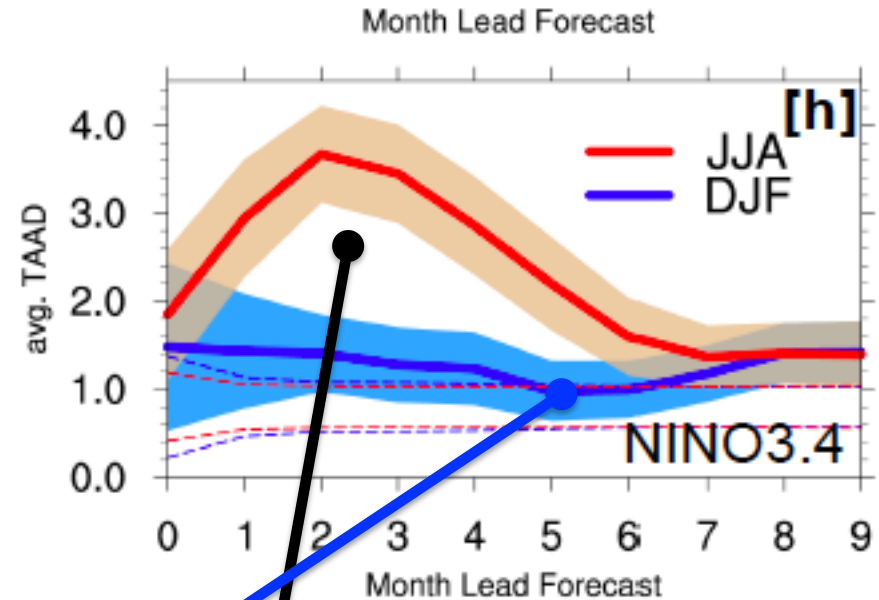
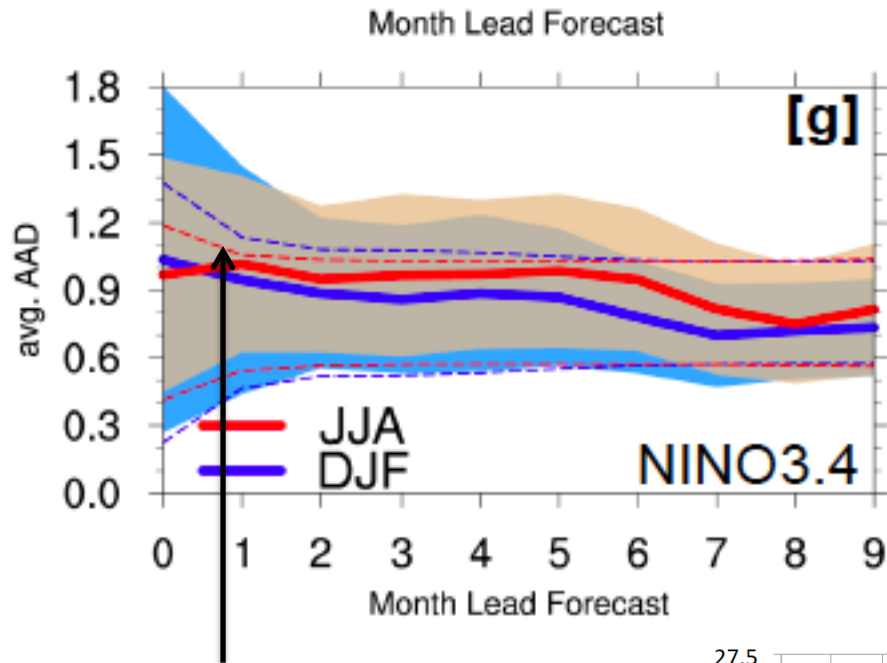
TAAD Type (H0 rejected, H1 Part II)



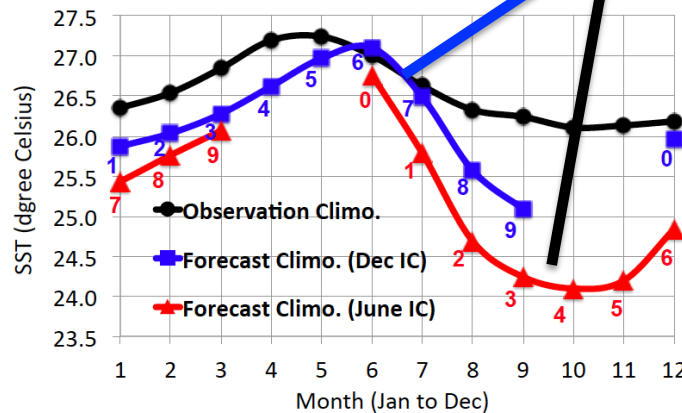
Hypothesis Testing in NINO3.4 region

AAD Type
(H0 not rejected)

TAAD Type
(H0 rejected, H1 Part II)

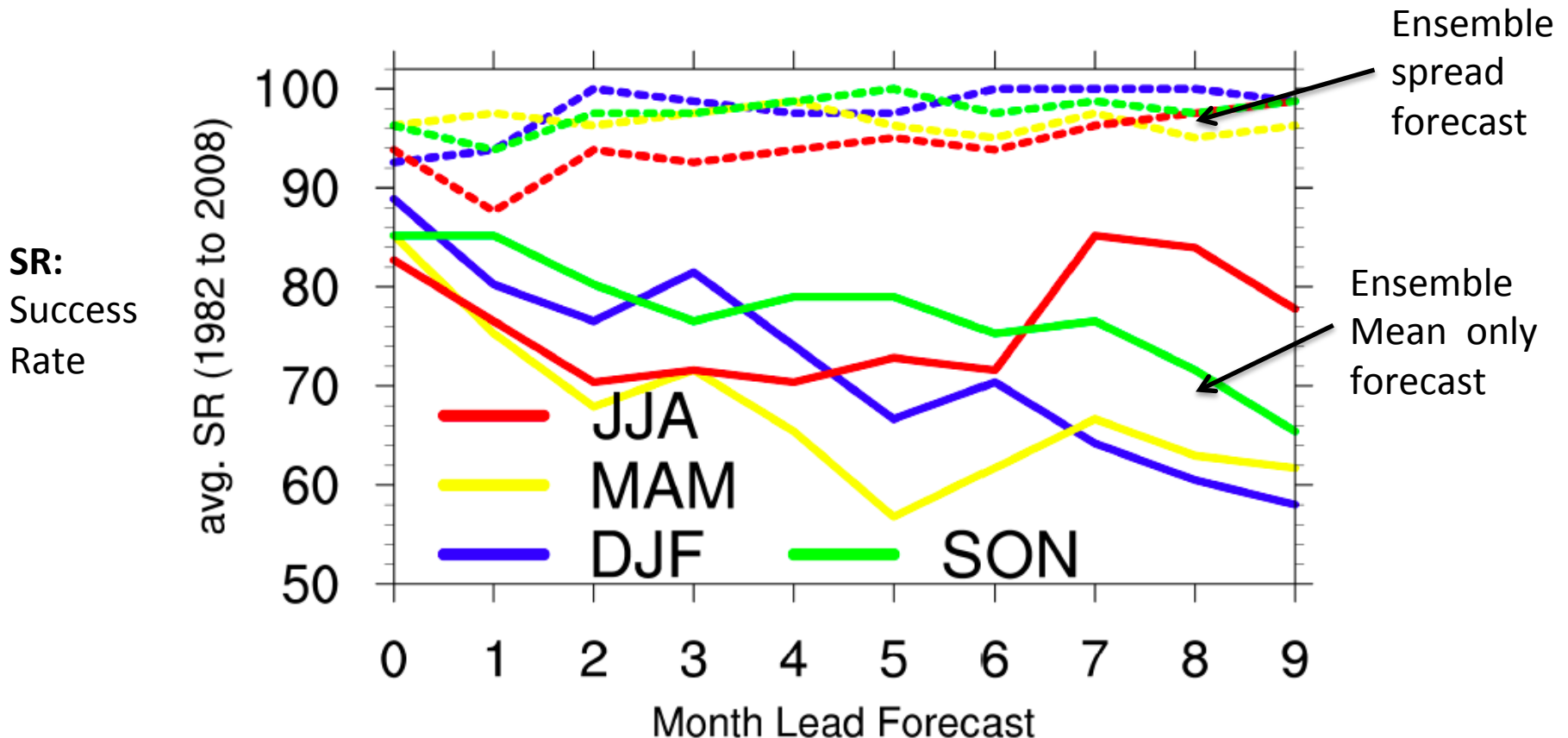


Effects of smaller
sample size (data with
ensemble spread <
0.25°C not considered)



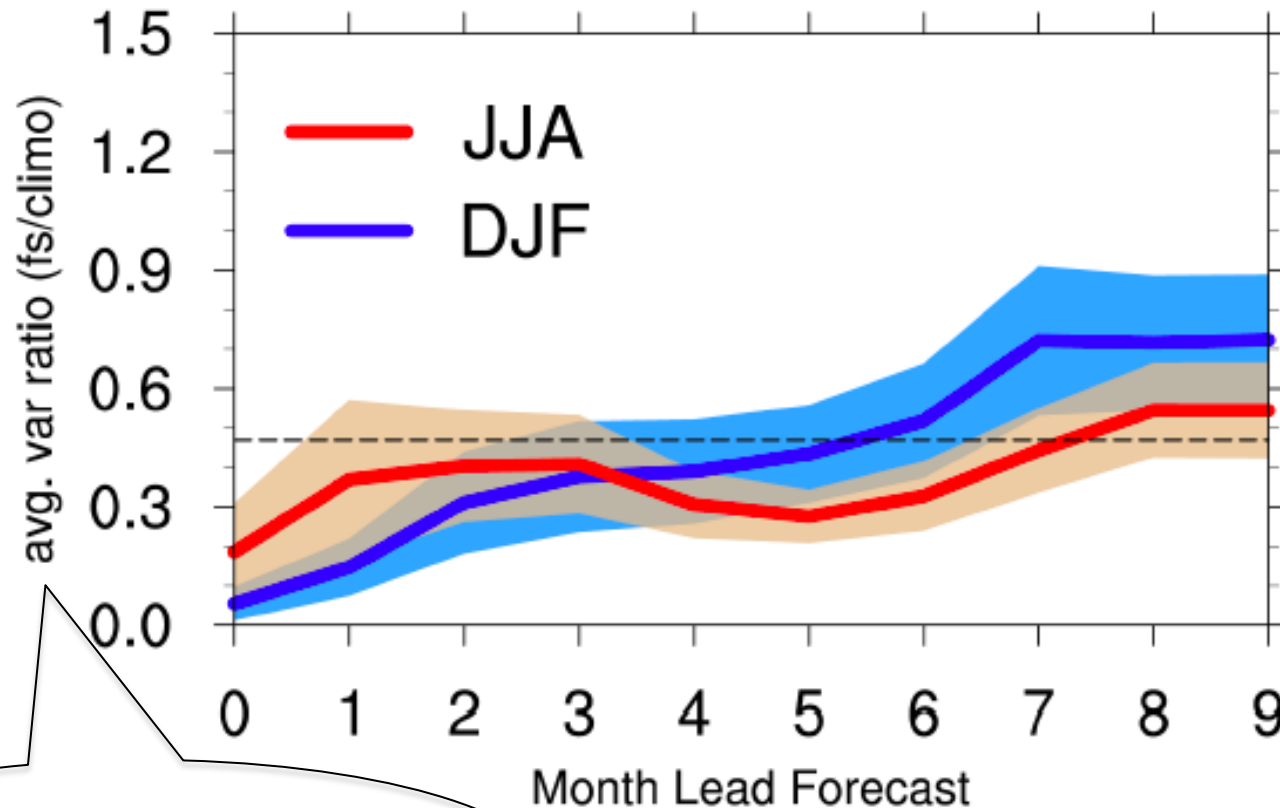
ENSO re-forecast verification (AAD type)

Is ensemble mean forecast is a reliable ENSO forecast?



Answer: YES for 60% times, and NO for 40% times for long lead (5 to 9 month lead) forecasts. But the observations are always contained within 95% ensemble spread range for all leads (broken lines in the figure)

Is the forecast ensemble spread smaller than inter-annual variability?

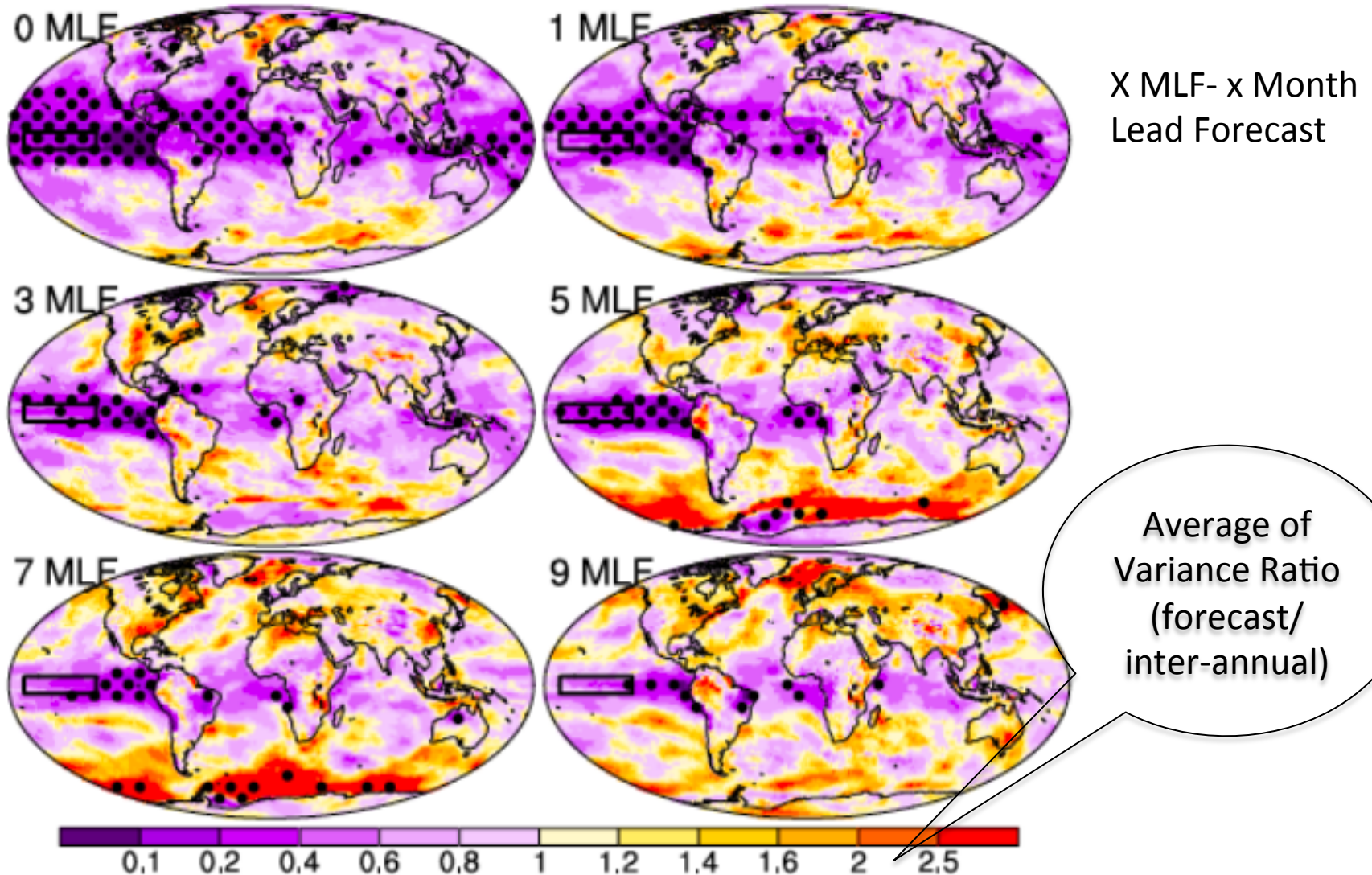


Average of Variance Ratio
(forecast/inter-annual)

Answer: YES in NINO3.4 region

What about other regions' forecast ensemble spread

[a] Average R JJA (1982 to 1998)



Conclusions

- 1.Forecast ensemble spread – a required component of the forecast (condition 1)**
- 2.Removal of systematic Biases – a function of forecast initialization month and lead time (condition 2)**
- 3.CFSv2 provides useful ensemble forecast even at longer-lead in several regions including NINO3.4 (provided conditions 1 and 2 are met)**

Interpretation for the operational forecast

Reforecast Configuration

24-members forecast
ensemble initialized 4-
times daily every 5th day
over the last 30 days

Operational Forecast Configuration

28-members forecast
ensembles initialized 4-
times daily in the last 7
days

We need same re-forecast and operational forecast configurations to correctly remove biases

Thank You